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Quantum simulation as *Technik*

The idea of quantum simulation, first conceived by Richard Feynman in his influential 1982 lecture "Simulating Physics with Computers"[2], introduced a peculiar shift not only to the notion of computer simulation but to the notion of simulation in general. In this paper, I examine how this shift in the notion of simulation is bound to change the way we think about the computer as a medium of art, as it amplifies the socioontological preoccupation of Media Art in the quantum age.

Computer simulation usually denotes the computation of solutions to, or the 'articulation' [3] of, a mathematical model of real-world processes. A necessary prerequisite to that, as to all human understanding of real-world processes, is a symbolic distance between the simulation and the simulated. Whereas purely language-based "description" realizes this symbolic distance as one big leap from the material to the symbolic, in terms of computer simulation we have to distinguish three consecutive steps: formalization (in the form of differential equations), discretization (in the form of difference equations), and mediatization (in the form of binary computation).

Each step realizes a higher level of abstraction, making the relation between the material and the symbolic at least as arbitrary as the relation invoked by purely language-based description. The simulation, however, is still recognized not only as a valid representation of the simulated (as a description would be), but as a model of the simulated, as a representation that not only points to the real-world process it represents but that claims to reproduce its functionality.[4]

Bruno Latour suggests that this preservation of functionality works because at every step of the process of abstraction

"each element belongs to matter by its origin and to form by its destination; it is abstracted from a too-concrete domain before it becomes, at the next stage, too concrete again. We never detect the rupture between things and signs, and we never face the imposition of arbitrary and discrete signs on shapeless and continuous matter."[5] The oscillation between the material and the symbolic[6] forms what Latour calls a "chain of

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[2] Feynman, Richard P.. "Simulating physics with computers". In: Journal of Theoretical Physics 21 (6), 1982: 467-488.

[3] Schweber, Sam; Wächter, Matthias. "Complex Systems, Modelling and Simulation". In: Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics 31 (4), 2000: 583-609.

[4] The exploration of this assumption's ontological truth is subject of a whole discourse within the history of science community. For an extensive overview see Frigg, Roman and Hartmann, Stephan, "Models in Science", The Stanford Encyclopedia of Philosophy (Fall 2012 Edition), Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/fall2012/entries/models-science/>.

[5] Latour, Bruno. "Circulating Reference: Sampling the Soil in the Amazon Forest". In: *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, MA, 1999. Interestingly enough, this is also how contemporary computers work: through levels of abstraction that each treat the levels below them as "black boxes" of which only certain "public" properties may be considered for further computation.

[6] Latour famously expands on this idea in his Actor-Network theory that he developed together with Michel Callon and that includes the idea of "translation" as its central concept. See Latour, Bruno.

reference".

The transformation from the material to the symbolic and the formation of an arbitrary relation between the material and the symbolic presents itself not as one big leap, but as a series of tiny jumps that are somewhat easier to digest, sometimes forward, sometimes backward, sometimes without any movement at all.

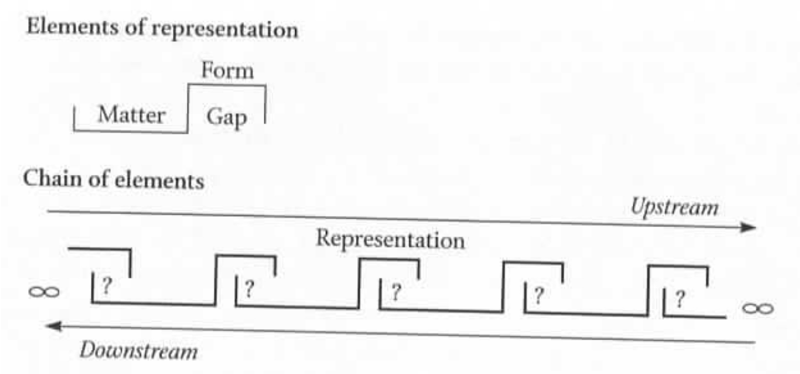

Fig. 1: Bruno Latour, the chain of reference[7]

For instance, as we measure a real-world process we come up with a series of symbols - in the case of computer simulation most likely numbers - that represent some property in space and time. In itself, this first step - formalization - is a complex achievement already, as it is based on a variety of basic human faculties (for instance the concept of the set[8]). The numbers, however, appear as "raw data"[9] to the next step in the chain of reference. Similarliy, at every step the symbolic is treated as material to the next level of abstraction.

In the light of this realization, let us look more closely at the three steps in the chain of reference that can be constructed for the notion of computer simulation. In the first step, data gained from the observation of material processes is casted into a differential equation. In the second step, this differential equation is treated as the material for a difference equation that usually involves some kind of approximation. In the final step, this difference equation is fed into a universal machine that calculates its results. The existence of an intermediate step of the "visualization" of some "raw data" is likeley but we are not concerned with this dimension of the chain of reference in this paper.[10]

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[7] Latour 1999, 70.
[8] It is no coincidence that all of mathematics can be constucted from set theory.
[9] As Claude Lévi-Strauss discovered that even the mythological antipodes of "raw" and "cooked" translate to well-structured abstract knowledge[9], it should not come as a surprise that "raw data" does not present itself as an antinomy to us. See Lévi-Strauss, Claude. *Mythologiques I : Le Cru et le cuit*. Paris: Plon, 1964.
[10] See Latour, Bruno. *Science in action. How to follow scientists and engineers through society*. Cambridge, MA, 1987. Inge Hinterwaldner explores this dimension - in particular regarding the

Our intuition tells us that this should be a more or less infallible method, given a good enough understanding of the real-world process we would like to model. As it turns out, however, the process has one critical breaking point that appears via its application to quantum processes. This breaking is part of the second step, discretization. Because quantum mechanics is inherently based on probability, discretization fails at a certain, not very high level of complexity of the simulated process.

As Richard Feynman explains, "one way that we could have a computer that simulates a probabilistic theory, something that has a probability in it, would be to calculate the probability and then interpret this number to represent nature."[11] But then we face

"a problem about discretizing probability. If you are only going to take k digits it would mean that when the probability is less that 2^{-k} of something happening, you say it doesn't happen at all. In practice we do that. If the probability of something is 10^{-700}, we say it isn't going to happen, and we're not caught out very often. So we could allow ourselves to do that. But the real difficulty is this: If we had many particles, we have R particles, for example, in a system, then we would have to describe the probability of a circumstance by giving the probability to find these particles at points x_1, x_2, ..., x_R at the time t. That would be a description of the probability of the system. And therefore, you'd need a k-digit number for every configuration of the system, for every arrangement of the R values of x. And therefore if there are N points in space, we'd need N^R configurations."[12]

Taking this even further, Feynman explains that we will most likely end up with an even higher number of configurations, like N^N, so that "doubling the size of nature" (meaning the part of nature that we are trying to simulate) would lead to an exponential growth in the required computational power.

The reason for the rupture in the chain of reference as we try to simulate a quantum system, as it thus turns out, is the excessive (usually exponential) complexity of inherently non-deterministic quantum problems within the deterministic computer systems of today. Hence, the goal of quantum simulation is to have "the number of computer elements required to simulate a large physical system [...] only to be proportional to the space-time volume of the physical system"[13] in order to reduce the complexity of such problems to be polynomial. That, however, is only possible if the physical system of the simulation has the same properties as the physical system of the simulated. This is where Feynman introduces the idea of quantum computing, of a computer performing calculations through basic elements (later called qbits) that make direct use of quantum processes, such as superposition and entanglement.

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operativity of visualizations - even further in Hinterwaldner, Inge. "Parallel Lines as Tools for Making Turbulence Visible". In: Representations 124 (1), 2013: 1-42

[11] Feynman 1982, 471

[12] Feynman 1982, 472

[13] Feynman 1982, 469

We will not go further into the technical aspects of quantum computing in the framework of this paper as the ontological consequences are strikingly evident at this point already: Quantum simulation means not only the simulation of quantum processes, but the simulation of quantum processes with quantum processes. Quantum simulation necessarily requires nothing less than the *simulated* to become the fabric of the *simulation*. Hence, for the notion of simulation, what used to be a complex process of negation through representation becomes identity, although a curious, not-quite, mediated kind of identity[14].

This assumption is validated by the fact that, in parallel to the research into quantum computers, or universal quantum simulators, there is a different strand of quantum simulation research that is concerned with experimental quantum simulation or non-universal quantum simulators. This kind of quantum simulator is only useful for the exploration of very specific quantum properties but is easier to realize. As Cirac et. al. put it, in comparison to a full, universal quantum computer, "if we are more modest and only demand our simulator to imitate certain physically interesting systems that cannot be simulated with classical computers, a[n experimental] quantum simulator may be easier to construct, but still would be an important device for the development of science and technology."[15]

So how does this shift in the notion of simulation affect our concept of the computer as a medium of art? I argue that it is through the socioontological preoccupation of media art that this effect takes place, as media art is inherently concerned with the socioontological reality of technology, with what Walter Benjamin describes as the "Technik" of a work of art.

The German original term - in comparison to the term "technique" that is usually used in translations - taken from Benjamin's famous essay “The Author as Producer”, points to the double character of technology use for a work of art. In the essay, there is a short translator's note on the term which is quite revealing: "Benjamin uses the word *Technik* to denote [the] aesthetic technique of a work, but with considerable scientific and manufacturing connotations. Thus it is also close to “technology” – the technical means by which a work is produced, its means of production"[16]. One should also note that when Benjamin speaks of the “work” ("Werk") instead of the "artwork" ("Kunstwerk") there is a similar connotation. "Werk" without the "Kunst" prefix connotates a mechanism (for example a clock) or even a whole factory. Additionally, I would go even further and say that "Technik" not only refers to the work's means of production but to the general relationships of production. As Benjamin puts it:

"Namely, instead of asking: what is the relationship of a work of art to the

[14] Of course classical computers are and always have been physical machines as well, machines that use material processes on the atomic level to represent abstract symbolic operations. In this regard, quantum simulation in general could be understood as merely a very specific application of computer simulation that requires a different, more specific set of tools. In regard to media art, however (...)

[15] Cirac, J. Ignacio; Zoller, Peter. "Goals and opportunities in quantum simulation". In: Nature Physics 8, 2012: 264-266. See also: http://www.sciencedaily.com/releases/2014/11/141127082317.htm

[16] Benjamin, Walter. "Der Autor als Produzent". In: *Gesammelte Schriften II-2*. Frankfurt am Main, 1974: 102.

relationships of production of the time? Is it in accord with them, is it reactionary or does it it strive to overthrow them, is it revolutionary? - in place of this question, or in any case before asking this question, I would like to propose another. Before I ask: how does a literary work stand in relation to the relationships of production of a period, I would like to ask: how does it stand *in* them?"[17]

This idea of standing "in" the relationships of production of a period is exactly what is expressed by the double meaning of "Technik". In other words: "Technik", in the context of art, is a technique somehow concerned with technology, or, more generally, a practice somehow concerned with the general relationships of production, or finally: a social practice.

This definition of "Technik" is closely related, as Benjamin points out, to the question of form and content: "I could have started from an older but no less sterile debate: what is the relation between form and content"[18]. Throughout the text, Benjamin seems to insinuate that commitment can either be a content-based artistic practice or a form-based artistic practice. The notion of "Technik" thereby gives us a way to grasp the dialectical relation of those two concepts operating in a work of art. Hence, for Benjamin, a politically committed artwork is always formally committed as well: "I want to show you that the political tendency of a work can only be politically correct [sic] if it is also literarily correct. That means that the correct political tendency *includes* a literary tendency"[19].

"Formal" commitment means changing technology through technique, thus changing the relationships of production – which is the goal of every "correct" (that is, for Benjamin at this point of his life, marxist-revolutionary) political tendency. The notion of "Technik" describes this momentum, that is practically achieved through the "organisational value" and the "exemplary character" of the artwork: "His [the authors] work would never merely be developing products, but always at the same time working with the means of production themselves. In other words, his productions must possess, in addition to and even before their characteristics as works, an organizing function"[20].

Adorno & Benjamin

"The logic of art, a paradox for extra-aesthetic logic, is a syllogism without concept or judgment. It draws consequences from phenomena that have already been spiritually mediated and to this extent made logical. Its logical process transpires in a sphere whose premises and givens are extralogical. The unity that artworks thereby achieve makes them analogous to the logic of experience, however much their technical procedures and their elements and the relation between them may distance them from those of practical empirical reality. The affiliation with mathematics that art established in the age of its dawning emancipation and that today, in the age of the dissolution of its idioms, once again emerges as predominant, marked art's emerging self-consciousness

[17] Benjamin 1974, 96
[18] ibd.
[19] ibd., 95
[20] ibd., 100

from its dimension of logical consistency. Indeed, on the basis of its formalism, mathematics is itself aconceptual; its signs are not signs of something, and it no more formulates existential judgements then does art; its aesthetic quality has often been noted."[21]

So, if Media Art is concerned with Technik as a dialectical synthesis of technology and form, the shift produced in the notion of computer simulation leads itself to the amplification of the socioontological component of media art.

(...)

This amplification, I posit, is part of what could be called the socioontological turn of media art that has been getting stronger and stronger since media art stopped being solely about the exploration of "new media" and started being about the socioontological implications of "new media".

As we have implied with our analysis of Benjamin - but what has to be emphasized again - the socioontological turn in media art is not about media art becoming political in the sense of "engagement". This kind of media art that is explicitly political exists of course. The socioontological turn, however, is about media art that is implicitly political, through its relation to its technology, through its "Technik".

One example is that quantum simulation also revives Friedrich Kittler's dogma that "there is no software"[22]. Kittler, in his seminal text of the same name, posits that the constraints present in computer hardware translate themselves through whatever number of levels of abstraction into the software dimension. Though Kittler's argument is mainly concerned with Foucauldian power relations inscribed in the hardware, it gains in persuasiveness in the light of quantum computing, as suddenly, we end up in the realm of the *post*-post-digital, where the chain of reference is a circle, the maximum level of abstraction leads right back to the concrete and all black boxes become translucent.

Historically, while the liquefaction of hardware with the invention and popularization of programmable logic devices, hardware description languages and related ideas was already a step towards this revival, quantum simulation is the pivotal concept for it to become a critical mass.

General trend, see Bio Art etc.: Overcoming of the boundaries of traditional media, exploration of all nature as a medium.

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[21] Adorno, Theordor W.. *Aesthetic Theory*. Translated by Robert Hullot-Kentor. London, New York, 2004, 6.
[22] Kittler, Friedrich. "Es gibt keine Software". In: *Draculas Vermächtnis: Technische Schriften*. Leipzig, 1993